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Carbon Sequestration: An Enhanced Performance Assessment System (EPAS)

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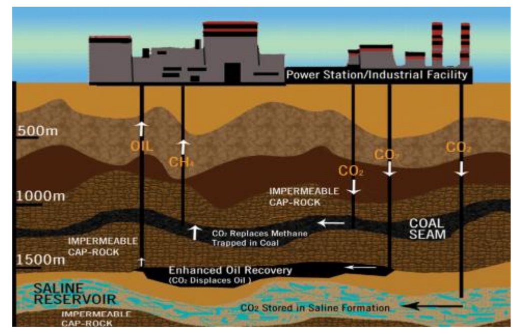
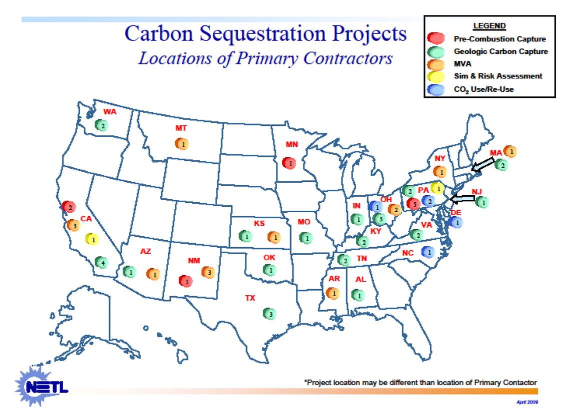
CARBON SEQUESTRATION AND UNCERTAINTY

Carbon capture and sequestration (CCS) is an option to mitigate impacts of atmospheric carbon emission. Sequestration has been proposed for saline aquifers, abandoned coal seams, oil/gas reservoirs, basalts. These systems have large uncertainties, both in the short term, and in their long-term performance.

To properly evaluate such systems, we followed the general PA methodology, a preliminary Feature, Event, and Process (FEP) analysis was performed for a hypothetical underground carbon storage system. Through this FEP analysis, relevant scenarios for CO_2 release were defined. For demonstration, a probabilistic PA analysis was successfully performed for a hypothetical underground carbon storage system based on an existing project in a brine-bearing sandstone in Texas. The work lays the foundation for the development of a new generation of PA tools for effective management of CS activities.



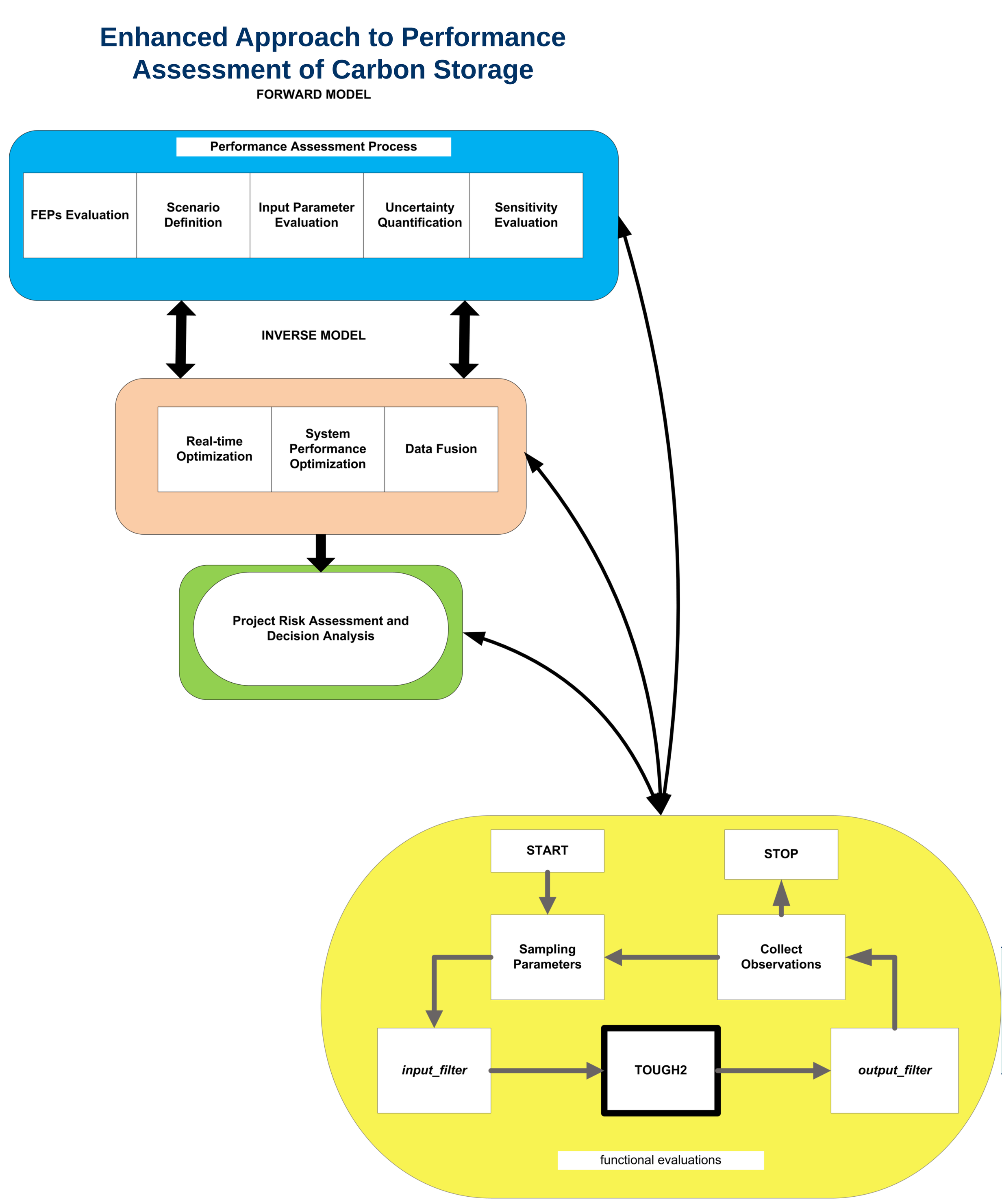
Conceptual diagram of CO_2 sequestration (WRI, 2010)

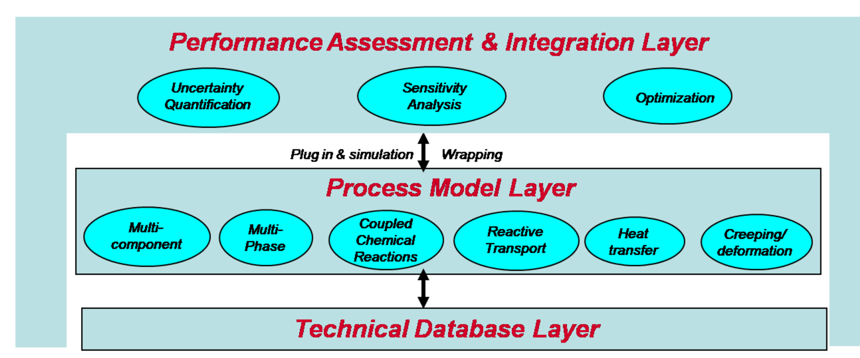


Map of Carbon Sequestration Projects in U.S. (NETL, 2010)

WHAT IS EPAS?

EPAS is an enhancement to the general modeling/simulation approach with a key improvement to link the uncertainty quantification and sensitivity tool with a flow and transport simulator for the reservoir. A prototype of EPAS was developed by wrapping an existing multi-phase, multi-component reservoir simulator (TOUGH2-ECO2N) with an uncertainty quantification and optimization code (DAKOTA). The capture and subsequent subsurface emplacement of CO_2 involves a number of processes, that have varying levels of uncertainty. But, a significant analysis of the processes can lead to confidence in the approach and the long term sequestration of the CO_2.





DAKOTA: Design Analysis Kit for Optimization and Terascale Applications

Key Capabilities

- Large scale engineering optimization and uncertainty analysis
- Utilization of sophisticated algorithms for:
  - ✓optimization,
  - ✓parameter estimation,
  - ✓uncertainty quantification,
  - ✓design of computer experiments, and
  - ✓parametric analysis

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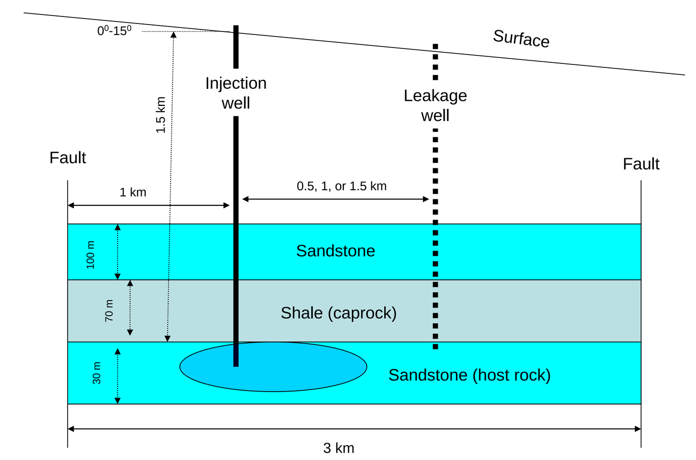
Schematic of DAKOTA-based EPAS framework

CONCEPTUAL MODEL

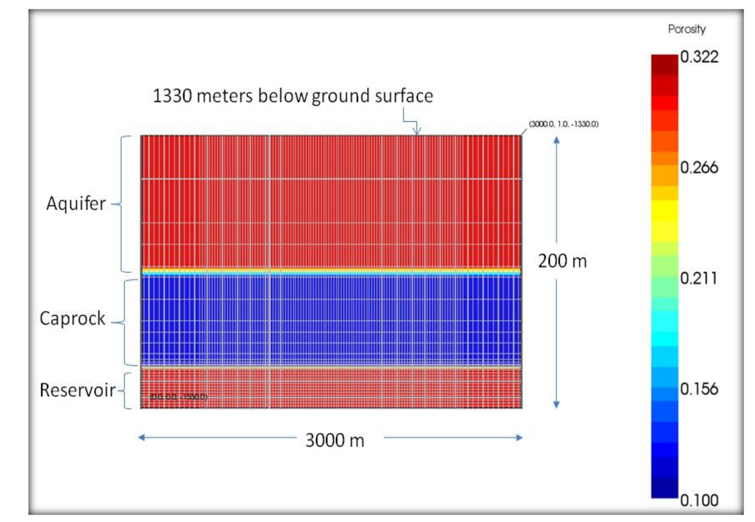
The initial conceptualization incorporates features, events and processes screened from the FEPs database (Quintessa, 2010).

MODELED SYSTEM:



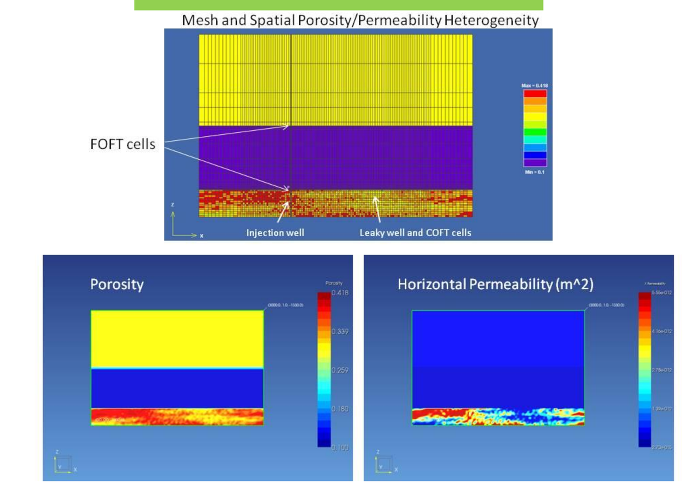
Evaluated scenarios with:
- leaking boreholes,
- leaking caprock, and
- potential impact on upper aquifer.

CONCEPTUAL MODEL:



Superimposed numerical grid for TOUGH2-ECO2N simulations.

MODEL DETAILS:

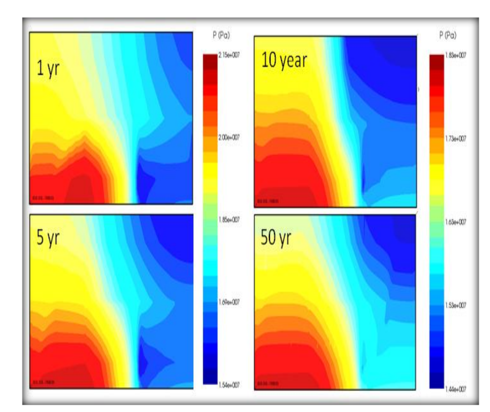


4160 grid cells, 48 input parameters, and 5 uncertain parameters: Injection rate, Productivity index for leaky well, Caprock porosity, Caprock permeability, and Caprock water saturation.

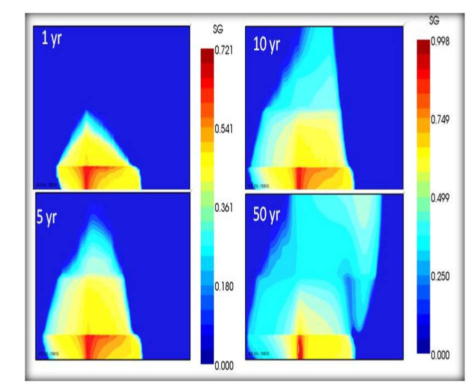
ANALYSES

The important findings from this research included identification of significant parameters to the performance of the system, as well as parameters whose values significantly affect the modeling ability of the system (e.g., permeability of the caprock and caprock-reservoir permeability contrast, injection rate).

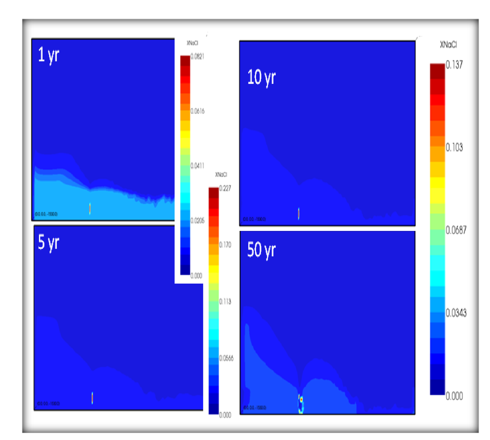
DETERMINISTIC ANALYSES:



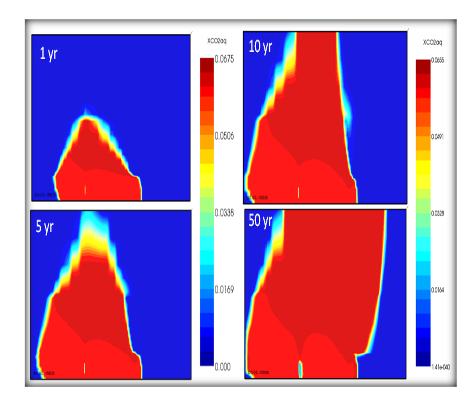
Pressure Profiles



$scCO_2$ saturation



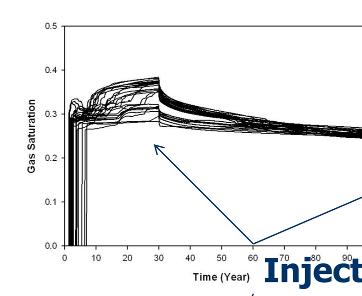
mass fraction of NaCl



aqueous CO_2

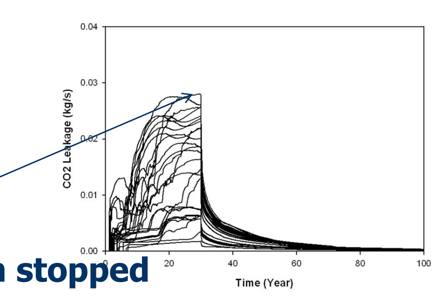
Key results of deterministic analyses:
- Rapid increase and dieoff of pressure with injection

MULTI-REALIZATION ANALYSES:

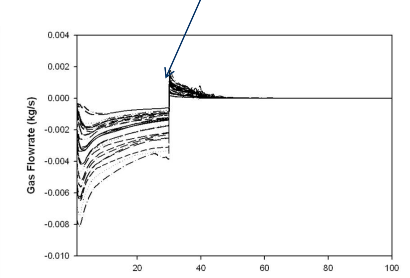


Injection stopped

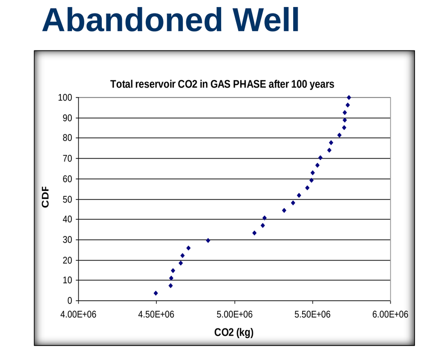
Gas Saturation in Abandoned Well



CO_2 Leakage from Abandoned Well



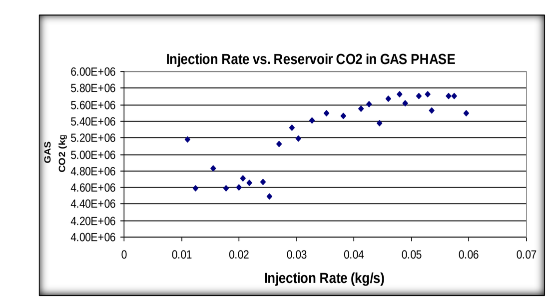
Gas Flowrate at the Reservoir-Caprock Boundary



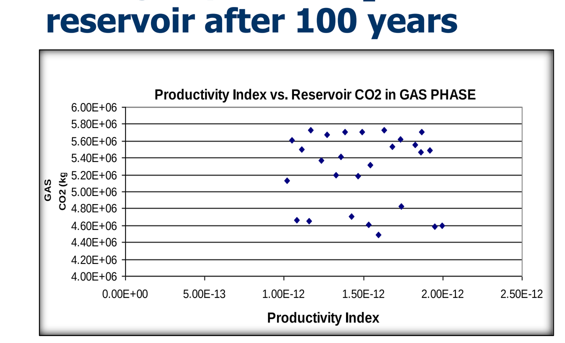
Total amount carbon dioxide in gas phase within reservoir after 100 years

Key results of multi-realization analyses:
- Parameter set compatibility issues
- Uncertainty high

SENSITIVITY ANALYSES:



Sampled injection rates versus total gas-phase CO_2 within the reservoir after 100 years



Sampled productivity indices versus total gas-phase CO_2 within the reservoir after 100 years

Key results of sensitivity analyses:
- Sensitive to injection rate
- No sensitivity to productivity index

FUTURE WORK

- Demonstrate full capability of the EPAS, especially for data fusion, carbon storage system optimization, and process optimization of CO_2 injection.
- Install the EPAS on a High Performance Computer.
- Apply the EPAS to actual carbon storage systems.

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